Enterprise Modelling Requirements for a Sustainability Multi Level Assessment

Khaled Medini, Catherine M. da Cunha, Alain Bernard

ENTERPRISE MODELLING REQUIREMENTS FOR A SUSTAINABILITY MULTI LEVEL ASSESSMENT

K. Medini, C. da Cunha, A. Bernard
LUNAM Université, Ecole Centrale de Nantes,
IRCCyN UMR CNRS 6597
1 Rue de la Noë, Nantes, France

Abstract
Pressure of governments, local communities and customers is urging organizations to consider sustainability in their development process. Sustainability should not be a separate concept from enterprise models. Moreover economic, environmental and social dimensions should be assessed at different organization levels namely product, process and supply chain. In this paper, sustainability concepts are presented, and then an investigation on enterprise modelling approaches is carried. The goal is to analyze the adequacy of these approaches with sustainability evaluation to highlight the need for an appropriate enterprise modelling approach that fits with sustainability assessment requirements.

Key words: Sustainability assessment, enterprise modelling approaches

1 INTRODUCTION

Sustainable development is a controversial debate that involves all society components. On the one hand governments, local communities and customers are getting more conscious about sustainability issues. On the other hand enterprises are trying to meet sustainability requirements while keeping economic profit as a priority. Thus sustainability assessment is not fully integrated in enterprises structure yet. Different levels within organization need to be considered in sustainability assessment namely product, process and supply chain. The integration of sustainability assessment at different levels within organization requires adequate enterprise modelling methods that support all enterprise levels. This paper aims at reporting analysis of extant enterprise modelling approaches compatibility with sustainability multi level assessment.

In section 2 a sustainability overview is carried out. Then the investigation on modelling approaches is presented in section 3. A synthesis is proposed at the end to summarize the analysis.

2 SUSTAINABILITY OVERVIEW

Sustainable Development first initiatives originated from the late 1970s when world commissions [1] were created to address concerns such as environment and development. In 1982 the World Commission on Environment and Development known as "Brundtland Commission" was created and began its work focusing on unity of development and environment [2]. Brundtland commissions published later in 1987 its report titled "Our Common Future" [3]. It defined sustainable development as "*ability to make development sustainable—to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs"*. The three dimensions of sustainable development namely economic, social and environmental were mentioned in Brundtland commission report. Nevertheless, there was a big focus on economic dimension in the early literature. Sustainable development definition was expanded in 2002 by world sustainable development commission [4] [5]. This new expansion included economic, environmental and social dimensions. In literature, those three pillars still have no common definitions or evaluation methods mainly at operational level [2] [6]. Furthermore, most Sustainable Development assessment frameworks have focused on national, regional or community level [7]. Little search focused on company level. During the late 1990s, Wupperal Institute for Climate, Environment and Energy Spangenberg and Bonniot [8] proposed an indicators system based on economic, social environmental and institutional dimensions [9]. In fact, the Wupperal Institute used the Commission on Sustainable Development (CSD) defined dimensions of sustainable development and established *interlinkage* indicators between these dimensions. The German Federal Environment Ministry (BMU) and German Federal Environment Agency (UBA) established an exhaustive list of environment indicators in 1997 [10]. Unlike previous frameworks, these indicators are applicable at enterprise level. Authors distinguished between environment performance indicators, environment management indicators and environment condition indicators. Environment performance indicators focus on organization's impact on environment. Performance indicators involve company's efforts to reduce impact on environment. Environment condition indicators depict the *quality* of environment surrounding the enterprise [10]. The most common framework that covered the entire organization is the Global Reporting Initiative [11]. GRI was meant to ensure reporting on enterprise performance. It specifies guidelines in reporting organizations performance based on sustainable indicators related to economic, social and environmental aspects [12] (see Figure 1).

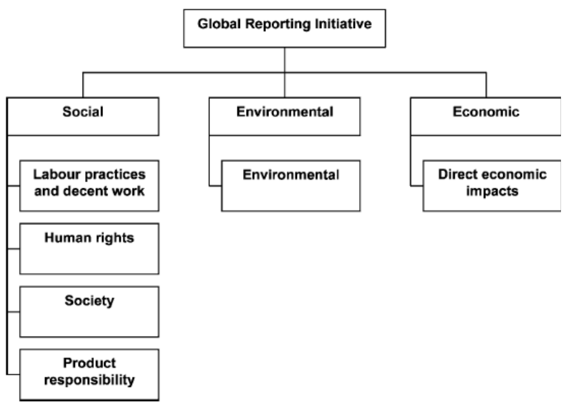

Figure 1: Global Reporting Initiative Sustainability Assessment Structure [11]

In 2000 the World Business Council for Sustainable Development proposed a methodology for Eco-efficiency assessment [13]. According to WBCSD Eco-efficiency consists in achieving *more value with lower inputs of materials and energy and with reduced emission*. The WBCSD proposed a set of general indicators that should be applicable for all organization. At the level of specific industries some guidance was proposed for indicators selection and implementation. Recommendations were also provided to clarify how to communicate eco-efficiency [14]. Another assessment framework was developed by the United Nation Commission on Sustainable Development in 2001. The framework was constructed to assess government's efforts in sustainable development [15] [7]. One year later, the Institution of Chemical Engineers introduced a standardized metrics framework that was environment oriented [16]. In 2004 Labuschagne [7] proposed a multi level framework to assess sustainable development at both strategic and operational levels in organizations. He distinguished between corporate social responsibility (CSR) and social sustainability of an industry. The CSR depicts organization's responsibility towards society. It is analyzed through enterprise's social involvement, poverty-focused investments and responsible implementation of core business activities. In this respect, Labuschagne assumed that corporate responsibility strategy consists of societal initiatives and operational initiatives. These latter are assessed according to economic, environmental and social criteria (see Figure 2).

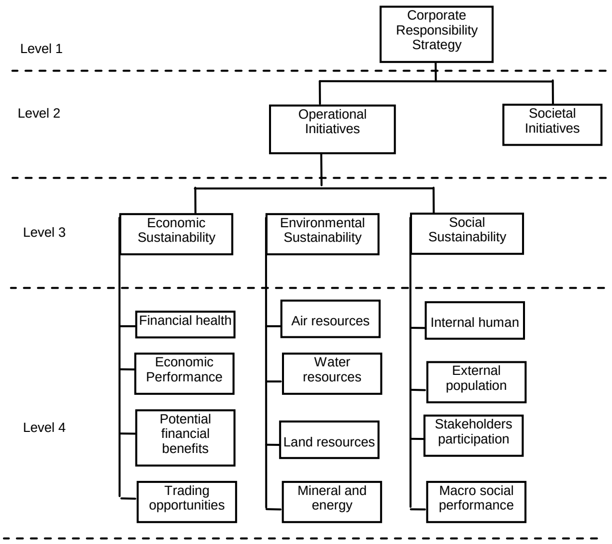

Figure 2: Multi level framework for sustainable development assessment [7].

Nevertheless, most of performance evaluation frameworks in terms of sustainable development focus mainly on external reporting and neglect somehow internal information that are essential in decision-making. Staniskis [17] proposed a set of criteria for indicators selection and an implementation method. According to Staniskis, indicators must fulfil certain criteria such as meaningfulness, clarity and efficiency. A well structured implementation methodology is also necessary to ensure achievement of management objectives.

While sustainability assessment models are being developed and improved, enterprise modelling approaches are not often taking into account sustainability issues. Sustainability needs to be evaluated at different levels of organizations [7], hence an effective enterprise modelling method must provide multi level model of organizations. Such a model facilitates integration of sustainability assessment methods and tools.

In the following section, most common enterprise modelling approaches were investigated in order to analyze their scope in terms of organization levels coverage. In fact, enterprise sustainability performance is tributary of product, process and the overall supply chain performance. Furthermore, sustainability itself is evaluated according to economic, social and environmental. Thus, enterprise modelling approaches will be analyzed according to organization levels namely: product, process and supply chain and sustainability pillars; economic, social and environmental dimensions.

3 ENTERPRISE MODELLING APPROACHES

Enterprise modelling includes frameworks such as CIMOSA, GERAM and TOGAF and approaches used to depict enterprise components. These approaches are used in the modelling frameworks to represent different views of an organization (see Figure 3).

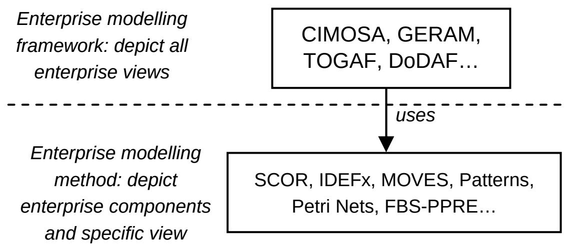

Figure 3: Enterprise modelling frameworks and methods

Hear we focus on modelling methods used to depict enterprise components (process, information flows, physical assets…). In the following, some design oriented methods and process analysis methods are depicted. These methods are chosen according to their eligibility to support sustainability assessment based on enterprise models. The output of such modelling methods is intended to be input for sustainability assessment methods.

3.1 « Graphes à Résultats et Activités Interreliées » (GRAI) : Analysis of manufacturing systems

GRAI was developed in the early 1980's by the Laboratory of Automation and Productics of University Bordeaux I [18] to design manufacturing management systems. The GRAI approach is based upon conceptual reference model, two graphical tools and an implementation methodology. The conceptual model is used to outline organization manufacturing system and to detail the activities of a decision centre [20].

According to GRAI conceptual model an organization consists of three subsystems namely physical, information and decision systems. The physical subsystem consists of physical means of production (i.e. machines, operators, techniques). The decision subsystem is split into decision making levels each one containing one or more decision centres. The information subsystem provides the link between the previous two subsystems [20] [21].

GRAI uses grids and nets to design and analyze an organization (see Figure 4). The GRAI grid is based on a top down analysis approach. It is represented by a matrix of columns and rows. The columns represent the functions within the organization and the rows define the hierarchical position of a decision centre defined by its time scale. Information flows are depicted by single arrows and relationship between decision centres is represented by double arrows.

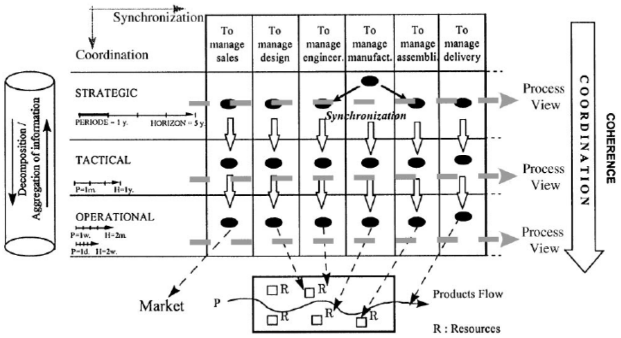

Figure 4: GRAI method [19]

GRAI nets depict activities made at each decision centre through a bottom-up analysis. Each activity has an initial and final state and produces results that can be the connecting resource to another activity [20] [22].

GRAI provides a view of the overall decision making process through grids and nets. The grids depict synchronization and coordination among stakeholders. GRAI nets ensure a better understanding of activities involved in decision making at each level of organization. Several extensions of GRAI nets were proposed in order to enlarge its scope, i.e. design process [23], performance evaluation [24]. The process view provided by GRAI method gives a partial vision of the supply chain since it deals with activities only within a same organization. This method is very useful when it comes to manufacturing systems analysis and improvement. In terms of sustainability, environmental and social considerations can also be considered as criteria for process improvement in addition to economic performance.

3.2 Integration Definition for Function Modelling (IDEF): Process depiction

During the 1970s the US Air Force Program for Integrated Computer Aided Manufacturing (ICAM) identified a series of techniques to improve production systems analysis namely IDEF0, IDEF1 and IDEF2. IDEF0 is a function model developed to represent functions, activities or processes within a system. IDEF1 is an information model that represents the semantics of a system's information. IDEF2 is a behavioral model that depicts time-varying behavioral characteristic of a system [25].

IDEF0 models are composed of graphic diagrams, text and glossary. Nevertheless major component is the graphic diagrams which are comprised of boxes and arrows.

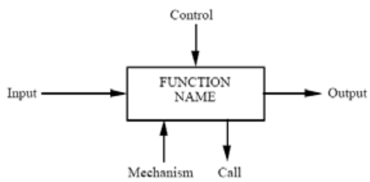

Figure 5: IDEF graphic diagram [23].

A box represents a function by a verb or a verb phrase. Input and output object or data flows are depicted by arrows. Control arrow is associated with the top side of an IDEF0 box. They represent condition required to provide correct output. Data or objects that are transformed by the function are depicted by the Input arrows. Output arrows depict produced objects or data. The mechanism used to perform a function is represented by Mechanism arrow. Mechanisms that enable sharing detail between models are represented by Call arrows (see Figure 5). IDEF0 is just a function model and doesn't apprehend dynamic aspects of a system. Some improvements have been made to support information and dynamic behaviour modelling in IDEF1 and IDEF2 [25]. During the 90's, IDEF3, a more complete version of IDEF was developed and has been widely used among industries. IDEF3 is based on the notion of scenario in process description. A scenario *can be thought of as a recurring situation, a set of situations that describe a typical class of problems addressed by an organization or system, or the setting within which a process occurs*. The knowledge acquisition is carried out according to process-centred strategy and object-centred strategy. Process centred strategy focuses on processes and their casual, temporal and logical relations within a scenario. The second strategy focuses on objects and their state change behaviour [26].

IDEF3 process description language is based on Units of Behaviour (UOB), objects, referents, junctions and links. UOB and referents are represented by labelled boxes. Circles depict objects and encompass object name and its state. Junctions are represented by small boxes with symbols denoting their types and links are depicted by arrows (see Figure 6).

Despite several improvements of IDEF since its introduction, product view remains out of its scope. It is rather a process oriented approach. Supply chain can also be depicted through its processes. Nevertheless sustainability dimensions are difficult to model using such a function view method. Hence sustainability performance analysis is out of its scope.

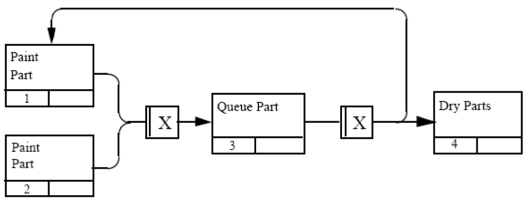

Figure 6: IDEF3 graphic diagrams [25]

3.3 Function/Behavior/Structure-Product/Process/Resource/External effect

FBS-PPRE is an extension of FBS model [27] [28] [29] proposed by Labrousse [31] and was claimed to support all enterprise objects modelling. He defined *Enterprise object* to encapsulate concepts of process, product and resource. According to Labrousse, an "Enterprise object" is defined *as an enterprise entity or an entity controlled by the enterprise*. An object plays role of process, product, resource or external effect during any stage of its life cycle, thus these roles are circumstantial [30] [32].

In FBS-PPRE model five categories of enterprise objects are defined namely, material, organizational, temporal, software and energetic. These objects are modelled through structural, functional, and behavioural views. Structural view consists in object decomposition into sub-objects. Functional view describes the object behaviour when it is used. Behavioural view is the touch points between process and the other object roles (product, resource, external effect), thus processes play a structural role in the model (see Figure 7). Transformations of the object structure carried out in the process are represented by the states (Sti).

FBS-model offers more completeness to the modelling of enterprise objects including process, product and resources. Use of process object facilitates depiction of supply chain level. The model can also be extended to integrate environmental, social and economic dimensions due to its completeness (i.e.: by use of sustainability attributes in the objects process and product). Nevertheless, its implementation would be quiet complicated for the same reason.

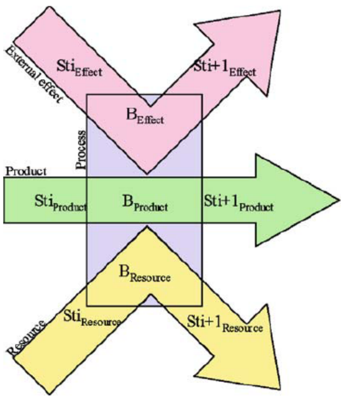

Figure 7: FBS-PPRE model [30].

3.4 Patterns based approach

Pattern concept was introduced in the late 1960s by Christopher Alexander [34]. The latter's researches involved architecture and were focused on interactions between people and physical spaces. He recorded results of observations in design patterns that provide generic solutions to problems and allow reuse of models. Patterns have been used among designers especially in software development [35] [36].

Gzara [33] proposed a set of design patterns for Product Information System management. Two classes of patterns were defined: processes for reuse and processes by reuse. The first class consists of generic solutions patterns. The second class involves tools to identify problems and supports the choice of most convenient patterns to solve these problems [30]. A product model and a process model were also proposed to improve model clarity. Basic concept of the product model is "Element" from which derive all components. Process model is based mainly on "Activity" concept that refers to Process or Operation.

Pattern approaches allow process and product knowledge capitalizing in order to be reused. Environmental and social dimensions of sustainability can be integrated through indicators and best practices.

3.5 Model for the Organization and the Validation of Enterprise Structures (MOVES)

MOVES model is a modelling approach developed in 2004 by Bennour [37]. It focuses mainly on resources assignment. In MOVES the human factor was integrated through the concept of competence [38]. The enterprise and some parts of its environment are integrated in the same model. In fact, MOVES Meta model (see Figure 8) encompasses enterprise objects which represent enterprise *stakeholders and technical objects involved in the process implementation*. According to MOVES model processes are controlled by organizational units and comprised of activities that can be broken down into tasks. The human or material stakeholders are required in the implementation of activities. Human stakeholders can be an individual or a group of individuals [37]. The link between human resources and activities is insured by the concept of "role" which also requires competences (see Figure 8).

Human factor and Process are basic components in MOVES. Performance estimation is also considered by Bennour through several concepts such as "competence" which impacts business domain performance. MOVES is very useful for enterprise performance evaluation. Nonetheless no big focus is carried out on product design or analysis. Social and environmental dimensions of sustainability are not depicted in this model but they can be integrated by introducing new objects in the model which gives it more completeness.

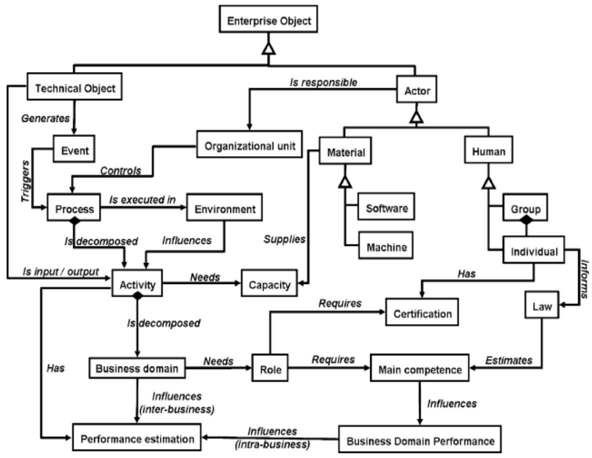

Figure 8: MOVES meta Model [37]

3.6 Supply Chain Operations Reference (SCOR)

SCOR is a business process reference model introduced by the Supply Chain Council in 1996 [39]. It integrates processes, metrics and best practices in a unified framework to improve supply chain management and communication.

The model is organized around the five primary processes namely Plan, Source, Make, Deliver and Return. When applied on specific supply chains, SCOR processes can be broken down into sub-processes that range from generic processes to detailed activities specific to those supply chains (see Figure 9). SCOR processes and sub-processes are grouped into three classes: planning, execution and enable. Planning processes ensure alignment of resources to meet expected demand. Execution processes includes scheduling, transforming material and services and product moving related activities. Enable processes manage and maintain information upon which Planning and Execution processes rely [39]. Such a model is able to support supply chain of various complexities and across multiple industries. All business activities involved in satisfying customer demand are described through the primary processes.

SCOR provides a number of multi level metrics to evaluate supply chain performance. The calculation of these is based on sub-metrics related to processes. A list of best practices was also established and is being updated continuously. SCOR is a process reference that has no focus on product. Nevertheless supply chain is a basic concept in SCOR model. The five generic processes used in such a reference depict standardized models of organizations as well as supply chains. Nonetheless metrics provided by SCOR are economic focused and no social neither environmental impact is measured though environmental dimension is lightly integrated in the model. It is depicted as a set of best practices.

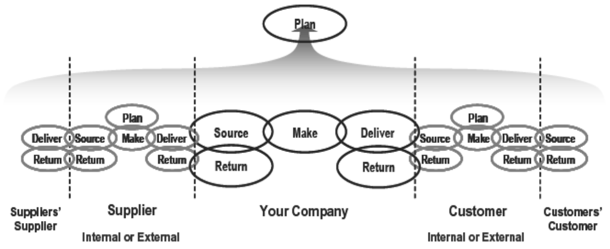

Figure 9: SCOR model [39]

3.7 Petri Nets

The concept of Petri net was introduced by Adam Carl Petri in 1966 [40]. Petri Nets are graphical and mathematical tools applicable to many kinds of systems. They are efficient tools in modelling *concurrent, asynchronous, distributed, parallel, nondeterministic and/or stochastic* systems [41].

A Petri net can be defined as a bipartite directed graph comprised of three types of objects: Places, transitions and arcs. These latter link Places to Transitions. Places are represented by circles and transitions by boxes or bars. Places can hold one or more tokens which are generally depicted by small solid dots. In market Petri net (a Petri net containing tokens) transitions can be enabled and fired resulting in a new marking with a new distribution of tokens. Such process is governed by enabling and firing rules [40].

Petri nets are widely used to describe systems and behaviour in time, for instance in batch process activities. Resources, process operations and conditions were modelled by places. Transitions were used to represent events. The existence of tokens implies that a resource is available, or an operation is ongoing or condition is true. Several other applications of Petri net in processes modelling was proposed in literature. A survey on Petri net applications on batch processes was presented in [40].

Petri Nets are used to depict and analyze behaviours of different kinds of systems in time. The tools provided in such a model allows describing process dynamics and resource constraints. Despite their large scope and many extensions, Petri Nets are not well adapted to sustainability performance analysis.

4 SYNTHESIS

As shown in Table 1, modelling approaches focus mainly on process level while supply chain is often partially supported. Furthermore, product level is out of many methods scopes.

In terms of sustainability, economic dimension is the most covered by enterprise modelling methods since it's the mainspring of companies. Environmental dimension has begun to merge into enterprise modelling approaches due to its increasing impact on enterprise branding. Nevertheless social considerations are not yet involved in modelling methods despite several attempts [3] [4] [5] [11] to integrate human being in the overall sustainability definition. Thus, sustainability assessment requires a more complete modelling approach that supports all enterprise levels as well as sustainability pillars.

An adequate enterprise modelling method for sustainability multi level assessment must depict enterprise objects including product and processes. Interrelationships between these objects need also to be depicted. Once such a model is available, a mapping to sustainability pillars could by then be carried out in order to get an integrated multi level assessment model.

Table 1: Enterprise modelling approaches analysis

	Organization levels			Sustainability pillars		
	Product	Process	Supply Chain	Environmental	Social	Economic
GRAI	X	X	/	*	*	/
IDEF		X	*			
FBS-PPRE	X	X	/	*	*	/
Patterns	X	X		*	*	/
MOVES	X	X	*	*	*	X
SCOR		X	X	/		X
Petri Nets		X	*			
Legend	X	Supported				
	/	Partially supported				
	*	Method can be extended to support				

Among the analyzed methods, GRAI and FBS-PPRE meet the most of the aforementioned requirements. In fact, GRAI extensions gave it more completeness and allow it to support both processes and products. Nevertheless interrelationships between these enterprise objects are more highlighted within the FBS-PPRE approach which also uses several key concepts, i.e. product, process, resource, etc. A potential alternative to be chosen in the future is to partially use FBS-PPRE in order to provide an integrative enterprise modelling for sustainability performance assessment.

5 CONCLUSION

In this study an overview of sustainability and enterprise modelling approaches was carried out. These latter were analyzed according to their scope. The mapping carried out in the last section showed that most of enterprise modelling approaches does not consider all enterprise levels namely product, process and supply chain. Moreover, sustainability pillars especially environmental and social dimensions are often not supported in enterprise modelling despite their crucial role in sustainability assessment. Thus a more adequate enterprise modelling approach is required to satisfy these criteria. One way to get such an approach is to improve some of the existing ones by integrating sustainability concepts at different enterprise levels. This issue is being addressed in the European Project *Sustainable Mass Customization - Mass Customization for Sustainability (SMCS)* [No. FoF-NMP-2010-2]. In fact, methods and tools are being developed to assess and improve sustainability and mass customization performance at product, process and supply chain levels.

6 ACKNOWLEDGMENTS

This work has been partly funded by the European Commission through S-MC-S (Sustainable Mass Customization – Mass Customization for Sustainability) project (Grant Agreement No: FoF.NMP.2010-2 260090 - S-MC-S).

7 REFERENCES

[1] Independent Commission on Disarmament and Security Issues, Common Security: A Blueprint for Survival, Palme Report, New York: Simon & Schuster, 1982; and Independent Commission on International Development Issues, North-South: A Program for Survival, Brandt Report, Cambridge, MA: MIT Press, 1980.

[2] Kates R. W., Thomas M. P., Leiserowitz A. A., What is Sustainable Development? Goals, Indicators, Values, and Practice, Environment: Science and Policy for Sustainable Development, 2005, 47, 3, 8-21.

[3] World Commission on Environment and Development, Our Common Future, New York: Oxford University Press, 1997, 8.

[4] United Nations, 2002, Johannesburg Declaration of Sustainable Development, New York.

[5] United Nations, 2002, Report of the World Summit on Sustainable Development, New York.

[6] Briassoulis H., Sustainable Development and its Indicators: Through a (Planner's) Glass Darkly, Journal of Environmental Planning and Management, 44, 3, 409 - 427.

[7] Labuschagne C., Brent A. C., van Erck R. P. G., Assessing the sustainability performances of industries, Journal of Cleaner Production, 2004, 13, 4, 373-385.

[8] Spangenberg J. H., Bonniot O., Sustainability Indicators- A Compass Towards Sustainability, 1998, Wupperal Institute for Climate, Environment, Energy.

[9] Valentin A., Spangenberg J. H., A guide to community sustainability indicators, Environmental Impact Assessment Review, 2000, 20, 381-392.

[10] Federal Environment Ministry, Federal Environmental Agency, 1997, A Guide to Corporate Environmental Indicators, Germany.

[11] Global Reporting Initiative, Sustainability reporting guidelines. Boston, Global Reporting Initiative, 2002.

[12] Brown H. S., de Jong M., Lessidrenska T., The rise of the Global Reporting Initiative: a case of institutional entrepreneurship, Environmental Politics, 2009, 18, 2, 182-200.

[13] World Business Council for Sustainable Development, eco-efficiency: creating more value with less impact, World Business Council for Sustainable Development, 2000.

[14] Verfaillie H. A., Bidwell R., measuring eco-efficiency: a guideline to reporting company performance, World Business Council for Sustainable Development, 2000.

[15] United Nations, Indicators of Sustainable Development: Guidelines and methodologies, United Nations, 2001.

[16] Sustainable Development Working Group, The Sustainability Metrics, The Institution of Chemical Engineers, 2002.

[17] Staniskis J. K., Arbaciauskas V., Sustainability Performance Indicators for Industrial Enterprise Management, Environmental Research, Engineering and Management, 2009, 48, 2, 42-50.

[18] Doumeingts G., Méthode GRAI: Méthode de conception des systèmes de productique, Phd Thesis, Université de Bordeaux I, France, 1984.

[19] Ducq Y., Vallespir B, Doumeingts G., Coherence analysis methods for production systems by performance aggregation, International Journal of Production Economics, 2001, 69, 23-37.

[20] Wainwright C. E. R., Ridgway K., 1994, Application of GRAI as a Framework for Manufacturing Strategy Process, Proc. of the 4th International Conf. on Advanced Factory Automation, England, 294-301.

[21] Tucker D., Lenoard R., An Innovative Approach for Using the GRAI Methodology for Reengineering the New Product Introduction Process, The International Journal of Flexible Manufacturing Systems, 2001, 13, 177-193.

[22] Al-Ahmari A. M. A., Ridgway K., An integrated modelling method to support manufacturing systems analysis and design, Computers in Industry, 1999, 38, 225-238.

[23] Benoît E., Modélisation du produit et des activités de conception - Contribution à la conduite et à la traçabilité du processus d'ingénierie, Phd Thesis, Université de Bordeaux I, France, 1999.

[24] Ravelomanantsoa M. S., Contribution à la définition d'un cadre générique pour la défintion, l'maplantation et l'exploitation de la performance : Application à la méthode ECOGRAI, Phd Thesis, Université de Bordeaux I, France, 2009.

[25] Federal Information Processing Standard, Integration Definition for Function Modelling, Federal Information Processing Standard, 1993.

[26] Mayer R. J., Menzel C. P., Painter M. K., deWitte P. S., Blinn T., Perakath B., Information Integration for Concurrent Engineering (IICE) IDEF3 Process Description Capture method Report, University Drive East, Texas, 1995.

[27] Gero A., Design Prototypes: Knowledge Representation Schema for Design, Artificial Intelligence Magazine, 1990, 11, 4.

[28] Gero J.S., The Situated function-behavior-structure Framework, University of Sydney, Sydney, 2006.

[29] Vermaas P. E., Dorst K., On the conceptual framework of John Gero's FBS-model and the prescriptive aims of design methodology, Design Studies, 2006, 28, 2, 133-157.

[30] Labrousse M., Proposition d'un modèle conceptuel unifié pour la gestion dynamique des connaissances d'entreprise, Phd Thesis, Ecole Centrale de Nantes, France, 2004.

[31] Bernard A., Labrousse M., Perry N., 2005, Life-cycle universal model as the base of enterprise information system structure, Innovation in Life Cycle Engineering and Sustainable Development, edited by: Brissaud, D., Tichkiewitch, S. and Zwolinski, P., Netherlands, 429-446.

[32] Labrousse M., Bernard A., FBS-PPRE, an Enterprise Based Knowledge Life Cycle Model, Methods and Tools for Effective Knowledge Life-Cycle-Management, 2008, 285-305.

[33] Gzara L., Les Patterns pour l'Ingénierie des Systèmes d'Information Produit, Phd Thesis, Institut National Polytechnique de Grenoble, Grenoble, France, 2000.

[34] Alexander C., Ishikawa S., Silverstein M., Jacobson M., Fiksdahl-King I., Angel S., A Pattern Language, Oxford University Press, 1997.

[35] Van Welie M., Van der Veer J. C., 2003, Pattern Languages in Interaction Design: Structure and Organization, Proc. of International Conference on Human-Computer Interaction, Zurich, Switzerland,

[36] De Souza M. A. F., Ferreira M. A. G. V., Designing reusable rule-based architectures with design patterns, Expert Systems with Applications, 2002, 23, 4, 395-403.

[37] Bennour M., Contribution à la Modélisation et à l'Affectation des Ressources Humaines dans les Processus, Phd Thesis, Université Montpelier II,Montpelier, France, 2004.

[38] Bennour M., Using competences in performance Estimation: from the activity to the process, Computers in Industry, 2007, 58, 2, 151-163.

[39] Supply Chain Council, Supply Chain Operations References Version 10.0, Supply Chain Council, 2010.

[40] Gu T., Bahri P. A., A survey of Petri net application iin Batch Processes, Computers in Industry, 2002, 47, 1, 99-111.

[41] Murata T., 1989, Petri nets: properties, analysis and applications, Proc. of IEEE, Chicago, 541-580.